

**What is claimed is:**

1. A method of interpolating image positions in an original image to produce an interpolated output image, wherein the original image is represented by digital input  
5 pixel data, comprising the steps of:

(a) providing a first filter having a sharp interpolation characteristic;

(b) providing a second filter having a smooth interpolation characteristic;

10 (c) interpolating a selected image position in the image using the first filter to generate a sharp interpolation output value;

(d) interpolating a selected image position in the image using the second filter to generate a smooth  
15 interpolation output value;

(e) calculating a weighting coefficient for the output of each filter; and

(f) selectively combining the output values from the filters as a function of the weighting coefficients, to  
20 generate an interpolation output value for the selected image position of an interpolated output image.

2. The method of claim 1, wherein in step (e) calculating the weighting coefficient for each of the two filters further includes the steps of:

estimating the image high frequency level at the  
5 selected image position; and

calculating a weighting coefficient for the output of the filter based on the estimated image high frequency level.

10 3. The method of claim 2, wherein the weighting coefficient  $\alpha$  for the first filter output is calculated according to the relation:

$$\alpha = \min(1, \max(0, (\varphi - T_1) / (T_2 - T_1)))$$

wherein  $\varphi$  is the image high frequency level  
15 estimated for the given interpolation position,  $T_1$  and  $T_2$  are two pre-determined threshold values where  $T_2 > T_1 \geq 0$ , whereby that the weighting coefficient for the second filter output is  $(1 - \alpha)$ .

20 4. The method of claim 2, wherein the interpolation output value  $q$  for the selected image position is according to the relation:

$$q = r * \alpha + s * (1 - \alpha)$$

wherein  $\alpha$  and  $(1-\alpha)$  are the weighting coefficients for the first and second filters, respectively ( $0 \leq \alpha \leq 1$ ), and  $r$  and  $s$  are the filter output values from the first and second filters, respectively.

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5. The method of claim 1, wherein:  
the first filter comprises a polyphase filter;  
and  
the second filter comprises a polyphase filter.

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6. The method of claim 5, wherein:  
the first filter comprises a one dimensional FIR polyphase filter; and  
the second filter comprises a one dimensional  
15 FIR polyphase filter.

7. The method of claim 5, wherein the two polyphase filters have the same length.

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8. The method of claim 5, wherein each of the polyphase filters comprises a  $N$ -tap  $M$ -phase polyphase filter.

9. The method of claim 8, wherein for arbitrary or variable interpolation ratios,  $M$  has a value of 10 or larger.

5 10. The method of claim 8, wherein  $N$  can be either an odd or an even number value.

11. The method of claim 5, wherein the two filters are low-pass filters, such that the first filter has a  
10 sharp frequency transition band and the second filter has a smooth frequency transition band.

12. The method of claim 8, wherein:  
calculating the weighting coefficient for each of  
15 the two filters further includes the steps of: estimating the image high frequency level at the selected image position, and calculating a weighting coefficient for the output of the filter based on the estimated image high frequency level; and  
20 the image high frequency level at the selected image position is estimated based on the image high frequency components measured at original image pixels neighboring the selected image position.

13. The method of claim 12, wherein the image high frequency component at the original image pixels is measured using a high-pass filtering process.

5 14. The method of claim 13, wherein the image high frequency component at the original image pixels is measured using a high-pass FIR filter.

15. The method of claim 13, wherein the image high  
10 frequency component  $\phi_i$  at each of the original image pixels is measured according to the relation

$$\phi_i = |p_i - 0.5 * (p_{i-1} + p_{i+1})|$$

wherein  $p_i$  is original image pixel value where image high frequency component is to be measured, and  $p_{i-1}$   
15 and  $p_{i+1}$  are values of its neighboring pixels.

16. The method of claim 15, wherein the image high frequency level  $\varphi$  at the selected image position is estimated according to the relation:

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$$\varphi = \sum_{i=-\frac{N}{2}+1}^{\frac{N}{2}} (0.5 * (f_{-i+1}^j + g_{-i+1}^j) * \phi_i)$$

wherein  $\phi_i, i = -\frac{N}{2}+1, \dots, 0, \dots, \frac{N}{2}$  are the image high frequency components calculated at the original image pixels that are within the filtering range of interpolation to the selected image position,  $f_i^j$  and  $g_i^j$  are filter coefficients of sub-filters  $f^j$  and  $g^j$  for the first filter and the second filter, respectively, and  $j$  is the interpolation phase for the selected image position.

17. The method of claim 12, wherein the image high frequency level at the selected image position is estimated based on the image high frequency components calculated at two original image pixels closest to the selected image position.

18. The method of claim 17, wherein the image high frequency level  $\varphi$  at the selected image position is estimated according to the relation:

$$\varphi = d_1 * \phi_0 + d_0 * \phi_1$$

wherein  $\phi_0$  and  $\phi_1$  are the image high frequency components calculated at the two closest original image pixels,  $d_0$  and  $d_1$  are the distances between the selected interpolation position and the two closest original image

pixel and the distance between two neighboring original image pixels is assumed to be 1, such that  $d_0 + d_1 = 1$ .

19. The method of claim 12, wherein the image high  
5 frequency level at the selected image position is estimated based on the image high frequency component measured at original image pixels that are within the filtering range of interpolation to the selected image position.

10 20. The method of claim 19, wherein the image high frequency level  $\phi$  at the selected image position is estimated according to the relation:

$$\phi = \sum_{i=-\frac{N}{2}+1}^{\frac{N}{2}} (0.5 * (f_{-i+1}^j + g_{-i+1}^j) * \phi_i)$$

wherein  $\phi_i, i = -\frac{N}{2}+1, \dots, 0, \dots, \frac{N}{2}$  are the image high  
15 frequency components calculated at the original image pixels that are within the filtering range of interpolation to the selected image position,  $f_i^j$  and  $g_i^j$  are the filter coefficients of sub-filters  $f^j$  and  $g^j$  for the first filter and the second filter, respectively, and  $j$  is the  
20 interpolation phase for the selected image position.

21. An interpolation system that interpolates image positions in an original image to produce an interpolated output image, wherein the original image is represented by digital input pixel data, comprising:

5 (a) a first filter having a sharp interpolation characteristic, the first filter interpolating a selected image position in the image to generate a sharp interpolation output value;

(b) a second filter having a smooth interpolation  
10 characteristic, the second filter interpolating the selected image position in the image to generate a smooth interpolation output value;

(c) a controller that calculates a weighting coefficient for the output of each filter; and

15 (d) a combiner that selectively combines the output values from the filters as a function of the weighting coefficients, to generate an interpolation output value for the selected image position of an interpolated output image.

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22. The system of claim 21, wherein the controller calculates the weighting coefficient for each of the two filters by estimating the image high frequency level at the selected image position, and calculating a weighting



coefficient for the output of the filter based on the estimated image high frequency level.

23. The system of claim 22, wherein the controller  
5 calculates the weighting coefficient  $\alpha$  for the first filter output according to the relation:

$$\alpha = \min(1, \max(0, (\varphi - T_1) / (T_2 - T_1)))$$

wherein  $\varphi$  is the image high frequency level estimated for the given interpolation position,  $T_1$  and  $T_2$   
10 are two pre-determined threshold values where  $T_2 > T_1 \geq 0$ , whereby that the weighting coefficient for the second filter output is  $(1 - \alpha)$ .

24. The system of claim 22, wherein the combiner  
15 determines the interpolation output value  $q$  for the selected image position according to the relation:

$$q = r * \alpha + s * (1 - \alpha)$$

wherein  $\alpha$  and  $(1 - \alpha)$  are the weighting coefficients for the first and second filters, respectively  
20  $(0 \leq \alpha \leq 1)$ , and  $r$  and  $s$  are the filter output values from the first and second filters, respectively.

25. The system of claim 21, wherein:

the first filter comprises a polyphase filter;  
and  
the second filter comprises a polyphase filter.

5        26. The system of claim 25, wherein:  
the first filter comprises a one dimensional FIR  
polyphase filter; and  
the second filter comprises a one dimensional  
FIR polyphase filter.

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27. The system of claim 25, wherein the two polyphase  
filters have the same length.

28. The system of claim 25, wherein each of the  
15 polyphase filters comprises a  $N$ -tap  $M$ -phase polyphase  
filter.

29. The system of claim 28, wherein for arbitrary or  
variable interpolation ratios,  $M$  has a value of 10 or  
20 larger.

30. The system of claim 28, wherein  $N$  can be either  
an odd or an even number value.

31. The system of claim 25, wherein each of the two filters comprises a low-pass filter, such that the first filter has a sharp frequency transition band and the second filter has a smooth frequency transition band.

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32. The system of claim 28, wherein:

the controller calculates the weighting coefficient for each of the two filters by estimating the image high frequency level at the selected image position, and calculating a weighting coefficient for the output of the filter based on the estimated image high frequency level, such that the image high frequency level at the selected image position is estimated based on the image high frequency components measured at original image pixels neighboring the selected image position.

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33. The system of claim 32, wherein the image high frequency component at the original image pixels is measured using a high-pass filtering process.

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34. The system of claim 33, wherein the image high frequency component at the original image pixels is measured using a high-pass FIR filter.

35. The system of claim 33, wherein the image high frequency component  $\phi_i$  at each of the original image pixels is measured according to the relation:

$$\phi_i = |p_i - 0.5 * (p_{i-1} + p_{i+1})|$$

5                wherein  $p_i$  is original image pixel value where image high frequency component is to be measured, and  $p_{i-1}$  and  $p_{i+1}$  are values of its neighboring pixels.

36. The system of claim 35, wherein the image high frequency level  $\varphi$  at the selected image position is  
10                estimated according to the relation:

$$\varphi = \sum_{i=-\frac{N}{2}+1}^{\frac{N}{2}} (0.5 * (f_{-i+1}^j + g_{-i+1}^j) * \phi_i)$$

                 wherein  $\phi_i, i = -\frac{N}{2}+1, \dots, 0, \dots, \frac{N}{2}$  are the image high frequency components calculated at the original image  
15                pixels that are within the filtering range of interpolation to the selected image position,  $f_i^j$  and  $g_i^j$  are filter coefficients of sub-filters  $f^j$  and  $g^j$  for the first filter and the second filter, respectively, and  $j$  is the interpolation phase for the selected image position.

37. The system of claim 32, wherein the image high frequency level at the selected image position is estimated based on the image high frequency components calculated at two original image pixels closest to the selected image  
5 position.

38. The system of claim 37, wherein the image high frequency level  $\varphi$  at the selected image position is estimated according to the relation:

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$$\varphi = d_1 * \phi_0 + d_0 * \phi_1$$

wherein  $\phi_0$  and  $\phi_1$  are the image high frequency components calculated at the two closest original image pixels,  $d_0$  and  $d_1$  are the distances between the selected interpolation position and the two closest original image  
15 pixels, the distance between two neighboring original image pixels is assumed to be 1, such that  $d_0 + d_1 = 1$ .

39. The system of claim 32, wherein the image high frequency level at the selected image position is estimated  
20 based on the image high frequency component measured at original image pixels that are within the filtering range of interpolation to the selected image position.

40. The system of claim 39, wherein the image high frequency level  $\varphi$  at the selected image position is estimated according to the relation:

$$\varphi = \sum_{i=-\frac{N}{2}+1}^{\frac{N}{2}} (0.5 * (f_{-i+1}^j + g_{-i+1}^j) * \phi_i)$$

5                    wherein  $\phi_i, i = -\frac{N}{2}+1, \dots, 0, \dots, \frac{N}{2}$  are the image high frequency components calculated at the original image pixels that are within the filtering range of interpolation to the selected image position,  $f_i^j$  and  $g_i^j$  are the filter coefficients of sub-filters  $f^j$  and  $g^j$  for the first filter  
10 and the second filter, respectively, and  $j$  is the interpolation phase for the selected image position.